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Probabilistic Seismic Hazard Analysis for Aceh Region

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Abstract. A study has been conducted to understand effect caused by earthquakes in Aceh. Using earthquake data from ISC, probabilistic seismic hazard analysis has been done to obtain informations how is the effect caused by earthquake sourced near Aceh. The results are peak ground acceleration, spectral acceleration for period of 0,2 and 1 Hz within return period 500 and 2500 years which equal to probability of exceedance 10% in 50 years and 2% in 50 years. There are several differences compared to results of study that had been conducted by Pusgen earlier in 2017. The results might be used as preliminary information to illustrate level of seismic hazard in Aceh.

1. Introduction

Aceh region is located in Sumatra Island of Indonesia. Every year, there are a lot of earthquake events happened in Aceh. According to ISC catalogs, from 1964 to 2017, there are about 16600 earthquakes happened in Aceh [1]. This can happen because Aceh is surrounded by some earthquake sources including faults, and subduction zone. The 2017 earthquake map and hazards released by PUSGEN [2] mentions that there are at least seven known faults that have recorded events. The latest famous earthquakes are the Pidie Jaya earthquake that struck in December 6th 2016 resulting in about 100 casualties [3] and the Central Aceh earthquake in 2013[4]. This event is really unique because the source is a fault that is relatively passive or has been inactive for a while. Aceh itself has several unknown faults yet has recorded events. These sources are usually named as background source [3]. Considering the amounts of earthquake happened in Aceh, thus it is necessary to know how vulnerable Aceh to effect of earthquakes. Since we know the sources of earthquakes in Aceh, then we can calculate or estimate effect of those earthquakes. We use probabilistic seismic hazard analysis to estimate effect of earthquakes that can struck Aceh region.

2. Data

2.1 Earthquake data

We use earthquake data from ISC catalogs as main source of earthquake data [1]. The area of research is limited by latitude between 2° – 7° N and by longitude between 93° – 100° E. Prior to area of research, the earthquakes used are those that happened within the area. There are about 16.600 events happened in this area between 1964 to 2017. Earthquakes that are considered to be used are not limited by magnitudes, therefore all recorded earthquakes are accounted. ISC earthquake data have various magnitudes. In order to calculate Peak Ground Acceleration, one has to uniform magnitudes into single type of magnitude. The most commonly type of magnitude used is moment magnitude of Mw. Moment magnitude is widely used because it does not saturate at large magnitude [6].



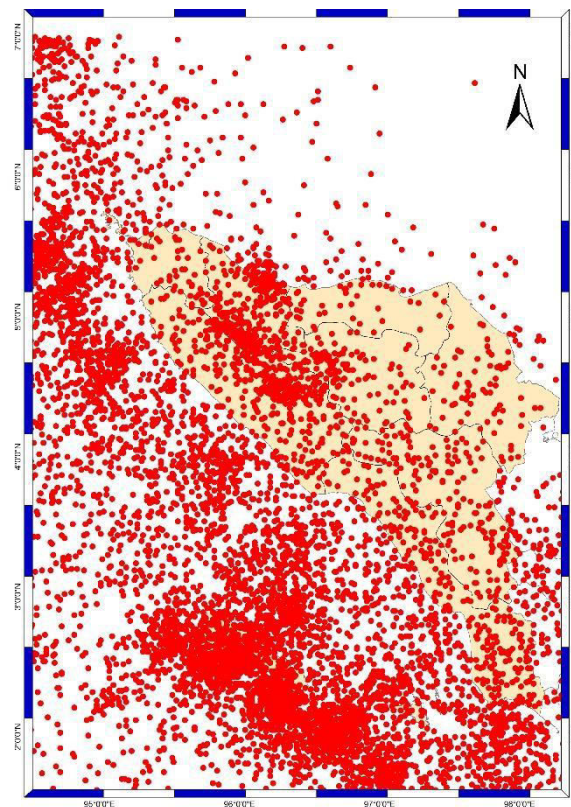


Figure 1. Earthquake data from ISC catalogs [1]

2.2 Source parameters

Probabilistic seismic hazard analysis requires not only earthquake data, but also parameter of possible source of earthquake within particular area. Source parameters used in this research are referred to the 2017 earthquake map and hazards of Indonesia released by PUSGEN [2] as well as the latest fault system in Pidie Jaya[3] and Aceh[4]. Probabilistic seismic hazard analysis accounted all possible source of earthquake.

The first source we all know is subduction zone. Subduction zone is widely known as one of source of earthquake which had been produced many devastating earthquake all over the world. One of them is Aceh earthquake which happened on 26th of December 2004. Next one is faults, which are spread across Aceh. The 2017 earthquake map and hazards released by PUSGEN mentions that there are at least 7 major faults in Aceh [2]. Those faults have experienced several earthquakes larger than magnitude of 6 [7]. The last source of earthquake is background. Background source is earthquake source which is not yet known but has recorded events [8].

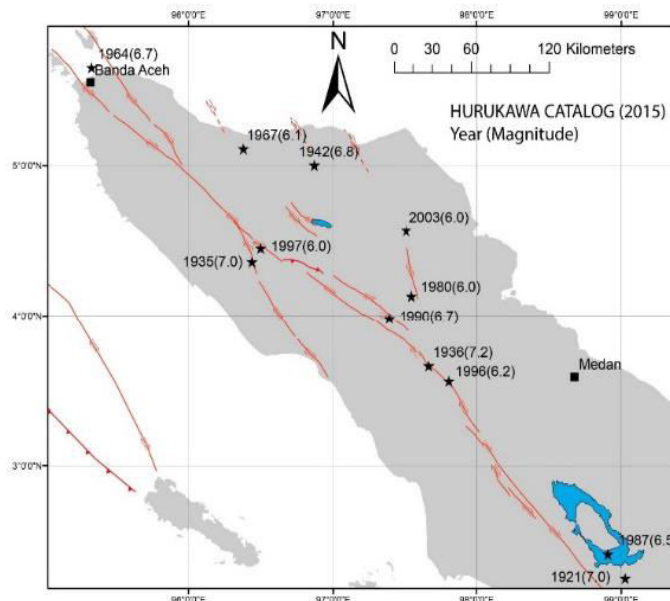


Figure 2. Earthquake sources in Aceh and historical earthquake from Hurukawa catalog [9]

Table 1. Parameter data of earthquake sources in Aceh [2] [10].

No.	Segment	Slip-rate (mm/yr)	Mechanism	Dip	Length (Km)	Top (Km)	Bottom (Km)	Mmax
1	Lhokseumawe	1,0	Strike-slip	90	36	3	20	6,5
2	Seulimeum-North	18,0	Strike-slip	90	143	3	20	7,6
3	Seulimeum-South	7,0	Strike-slip	90	38	3	20	6,9
4	Aceh-North	2,0	Strike-slip	90	65	3	20	7,2
5	Aceh-Central	14,0	Strike-slip	90	140	3	20	7,6
6	Aceh-South	14,0	Strike-slip	90	27	3	20	6,7
7	Lot tawar	0,5	Strike-slip	90	21	3	20	6,6
8	Peusangan	0,5	Strike-slip	90	32	3	20	6,8
9	Tripa 1	16,0	Strike-slip	45	32	3	20	6,8
10	Tripa 2	7,0	Strike-slip	90	103	3	20	7,4
11	Tripa 3	14,0	Strike-slip	90	75	3	20	7,3
12	Tripa 4	7,0	Strike-slip	90	55	3	20	7,1
13	Tripa 5	7,0	Strike-slip	90	21	3	20	6,6
14	Batee A	6,0	Strike-slip	90	44	3	20	7,0
15	Batee B	0,5	Strike-slip	90	50	3	20	7,0
16	Batee C	0,1	Strike-slip	90	37	3	20	6,9
17	Aceh-Andaman Megathrust	40	Thrust		1300			9,0

Faults parameters listed in the 2017 earthquake map and hazards released by PUSGEN [2] do not provide fault width. Fault width is required to do hazard analysis. Then we use Papazachos relations [11] to obtain that.

3. Methods

Probabilistic seismic hazard analysis aims to calculate potential ground motion caused by earthquakes which are sourced nearby certain area. It is really important for designing building codes regarding result of the analysis. There are several steps in order to do probabilistic seismic hazard analysis. Typically it can be written as below [12]

1. Identificating and characterizing all earthquake sources that potentially can produce significant ground motion and make.
2. Finding recurrence relationships, in order to define rate of recurrence of earthquake with certain magnitude at particular source.
3. Calculating the ground motion produced by certain earthquake with some particular magnitude at specific area using attenuation functions.
4. Combining of earthquake location, size and ground motion parameter estimation in order to obtain probability of ground motion parameter will be exceeded in given range of time.

Technically, probabilistic seismic hazard analysis is done by several steps [13]. First one needs to decluster the earthquake data in order to separate which earthquake is happened in which source then we can determine the type of each sources. Declustering the earthquakes is done by using Gardner and Knopoff Scheme [14] which is included in Zmap [15]. In order to avoid overestimate result of hazard analysis, main shock needs to be separated. Magnitude of the earthquake needs to be uniformed into moment magnitude, in this research, equation listed in the 2017 earthquake map and hazards released by PUSGEN [2] as well as the Aceh and Pidie Jaya fault system[3][4] are used. Then we find a-b value which is very important in this calculation. The value of a-b is obtained using Gutenberg-Richter equation included in Zmap [15]. Next, one needs to determine the earthquake source parameters in order to do hazard analysis [16]. Then we should choose ground motion equation for each type of source. Probabilistic seismic hazard analysis is done using USGS software developed by Harmsen [17].

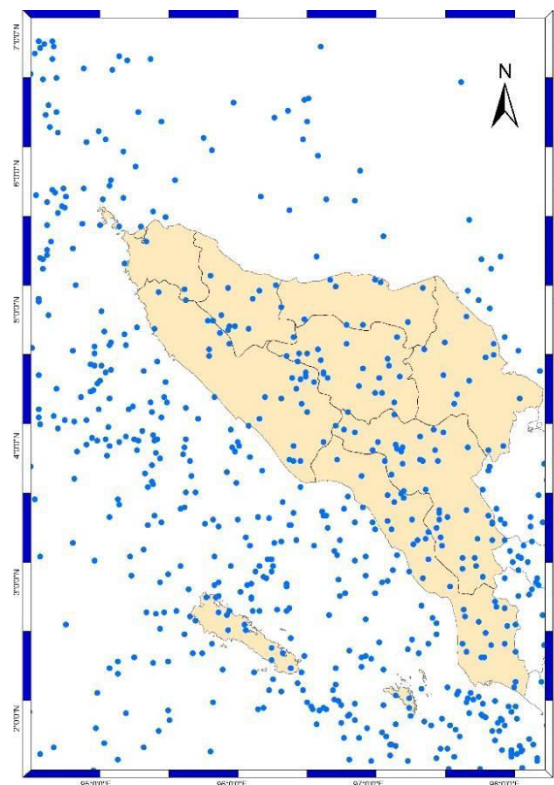


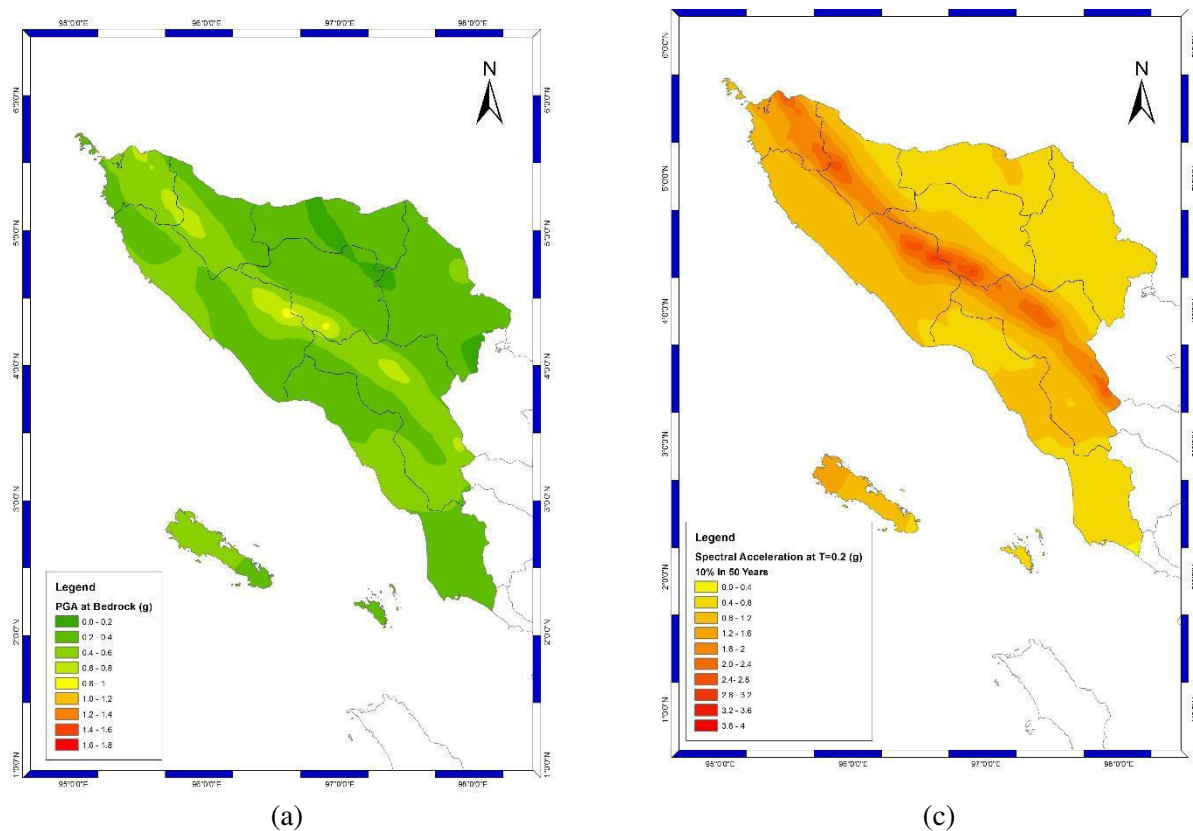
Figure 3. Earthquake data after being declustered.**4. Results and discussions**

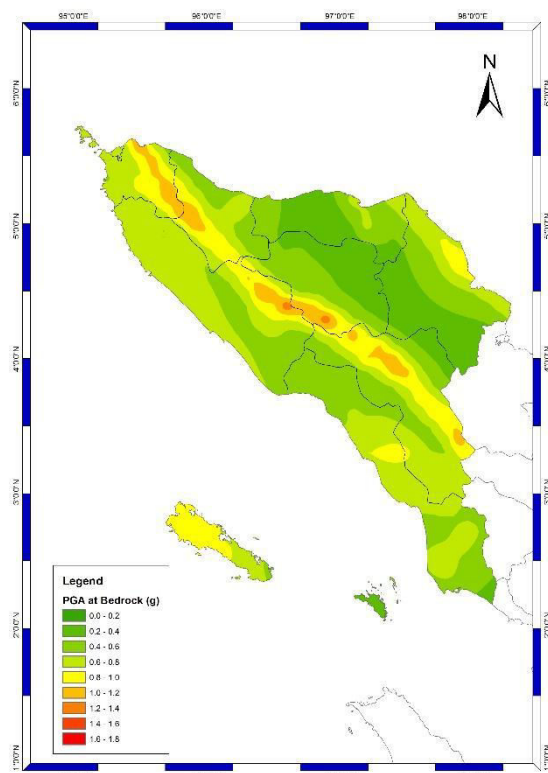
Probabilistic Seismic Hazard analysis had been done in order to obtain three parameters in two hazard levels [18] as listed in table 2. Parameters need to obtain are enlisted in Indonesian building codes. Indonesia building codes earlier [19] mentioned that recommended hazard level is 10% probability of exceedance in 50 years which is equal to 500 years earthquake return period. Later version of Indonesia building codes [20] revised the hazard level. It is said that 2% probability of exceedance in 50 years is the recommended hazard level which corresponds to 2500 years earthquake return period. Considering some buildings were built referred to earlier codes, in this research earlier hazard level is also calculated alongside later recommended hazard level.

Table 2. Parameters that will be obtained from PSHA.

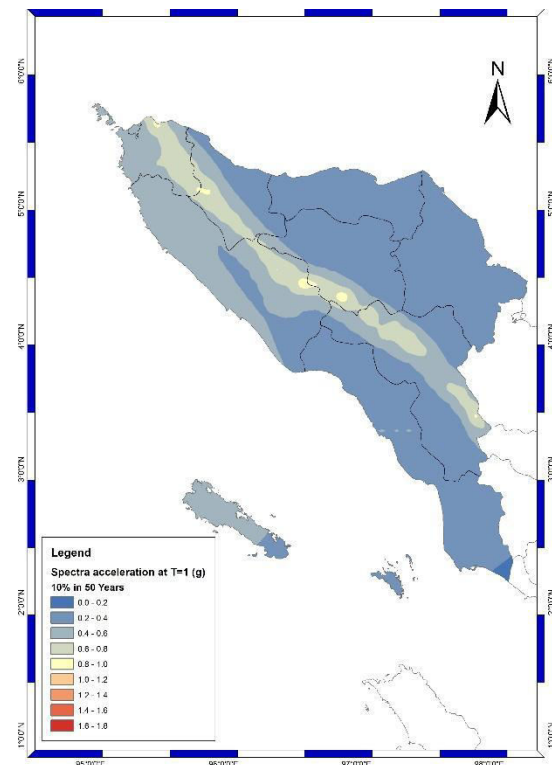
Hazard Level	PGA	T=0.2 second	T=1.0 second
10 % PE in 50 years	v	v	v
2% PE in 50 years	v	v	v

The results from probabilistic seismic hazard analysis are distributed spatially, then in order to read the data, the results are plotted into a map. Since the results are in form of grid, then we need to interpolate it using kriging to make contour maps. Three parameters in two hazard levels are individually plotted which resulted in six maps to read.

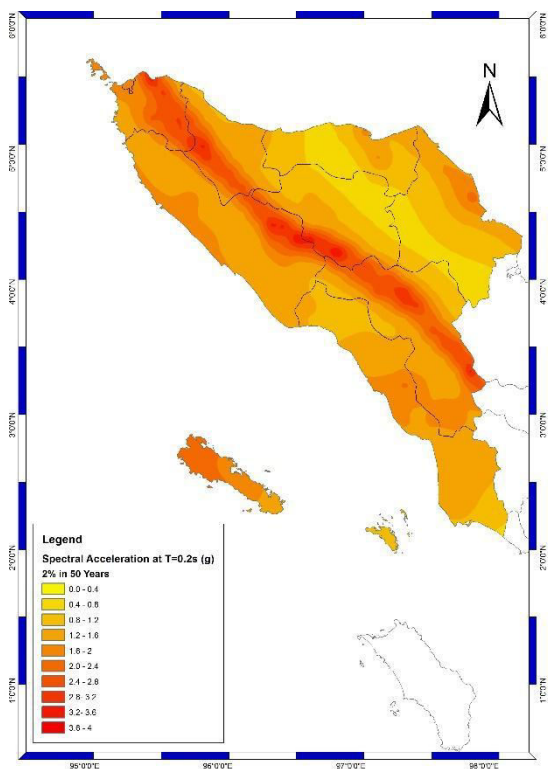




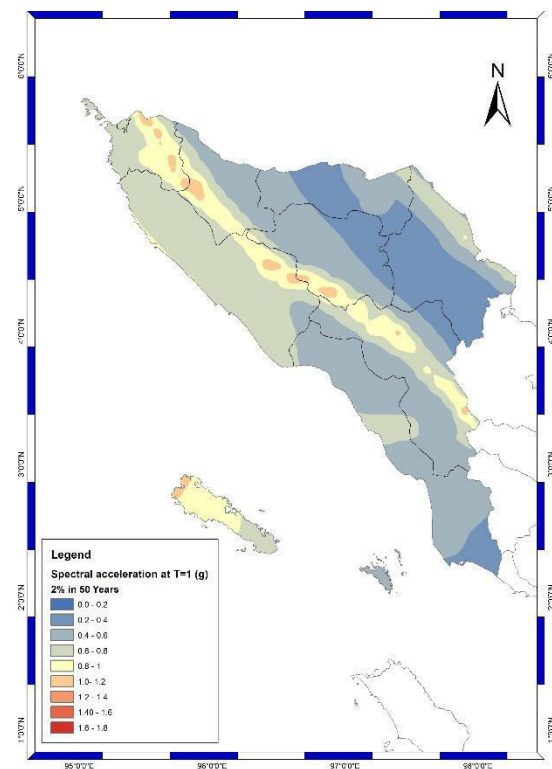
(b)



(e)



(d)

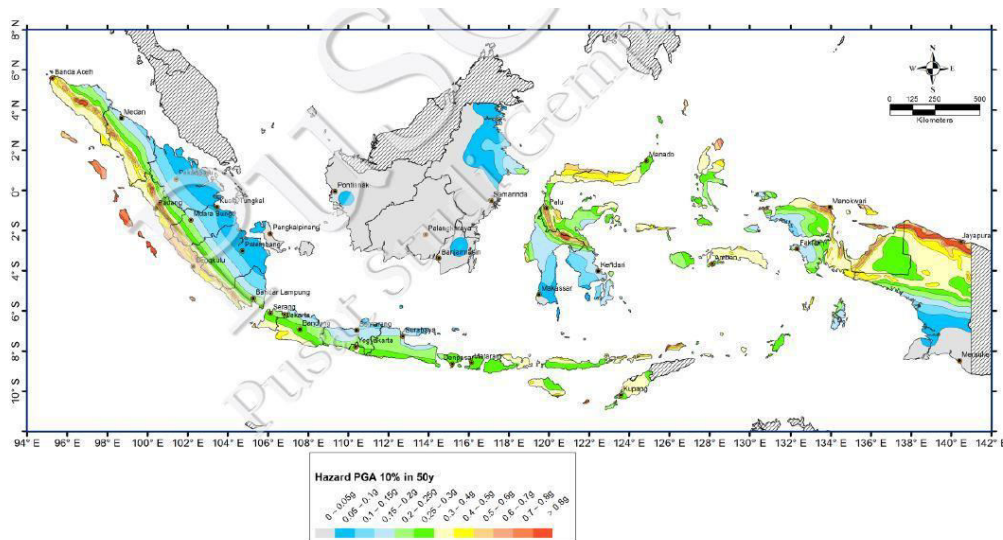


(f)

Figure 4. (a) Peak ground acceleration at bedrock with 10% probability of exceedance in 50 years, (b) peak ground acceleration at bedrock with 2% probability of exceedance in 50 years, (c) spectral acceleration map at bedrock for $T=0.2$ Hz with 10% probability of exceedance in 50 years, (d) spectral acceleration map at bedrock for $T=0.2$ Hz with 2% probability of exceedance in 50 years, (e) spectral acceleration map at bedrock for $T=1$ Hz with 10% probability of exceedance in 50 years, (f) spectral acceleration map at bedrock for $T=1$ Hz with 2% probability of exceedance in 50 years.

Figure 4 (a) shows that peak ground acceleration with 10% probability of exceedance in 50 years in Aceh has high value alongside middle part of Aceh and relatively lower in other part of area. The values vary from 0.1 to 1 g and have similar pattern with figure 4 (b) but (b) has higher value than (a). Figure 4 (c) and (d) share similar features. They have high value line in the middle part of Aceh and slightly lower value in northern part of the high value line. The differences are first, in figure (d) has high value line in northern and southern part of Aceh. Second is the value range, (c) has value ranges between 0.4 and 3.2 g while (d) varies from 0.4 to 3.6 g. Same features as (c) and (d) will be found in figure 4 (e) and (f) but with relatively lower values. Values in figure 4 (e) are ranged from 0.1 to 1 g, while (f) values are between 0.1 and 1.2 g. The island of Simeulue surprisingly has relatively high value in western part of island in all parameters. High value line can be found in middle part of Aceh because there we can find fault system which consists several major faults. While the reason Simeulue island has high value is because it is located near subduction zone. Areas near Langsa and Aceh Singkil also have slightly high value because there we found several earthquakes but the source is yet be defined. In this case, we put earthquakes in this area as earthquake related to background source. The point is, if the return period is longer, the acceleration will be larger.

Previous attempt to calculate peak ground acceleration in Aceh had been conducted by PUSGEN which results are shown below.



(a)

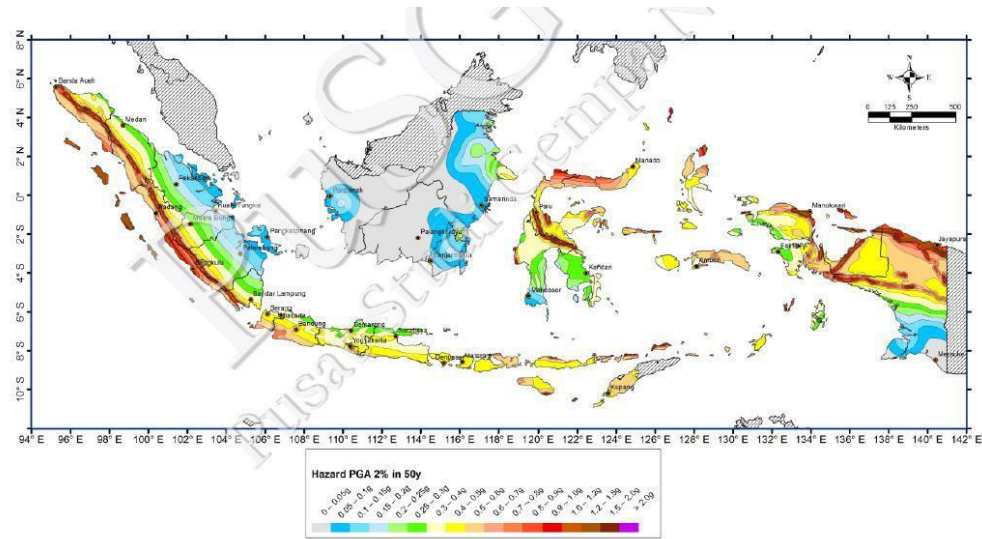


Figure 5. Results of PUSGEN studies, (a) Peak ground acceleration at bedrock with 10% probability of exceedance in 50 years, (b) peak ground acceleration at bedrock with 2% probability of exceedance in 50 years, (c) spectral acceleration map at bedrock for $T=1$ Hz with 2% probability of exceedance in 50 years, (d) spectral acceleration map at bedrock for $T=0.2$ Hz with 2% probability of exceedance in 50 years [2].

PUSGEN results when compared to our results, peak ground acceleration for 10% in 50 years from PUSGEN is slightly lower, while for 2% in 50 years our result values are lower than PUSGEN. These differences are caused by differences earthquake data used. Difference earthquake data will result in different a and b values. In the end it will produce different peak ground acceleration result. Another difference that our study and PUSGEN did is the area that is studied, our study only focused in Aceh while PUSGEN did for wider area.

5. Conclusions

Probabilistic seismic hazard analysis is useful to understand seismic hazard in such area. Our results have slight difference with PUSGEN produced. Difference in results are mainly caused by difference earthquake data used. Technically our results and PUSGEN results have similar features that are consistent in several hazard levels. Overall if certain area is near earthquake source, it will have higher ground motion than area which has larger distance to faults or subduction zone. It is shown by high value line in the middle of Aceh, near Simeulue island and near Langsa and Aceh Singkil. Analysis shows that if return period is longer, the ground motion produced will be larger. Our results which consistent to PUSGEN results, prove that.

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